ATM 316 Homework #8 Questions. Due 4 December 2019.
Fall, 2019 – Fovell

Part I: Information for the following questions: You are in the NH midlatitudes ($f > 0$). Let $\Delta p = 10$ mb over 1000 km, $\rho = 1$ kg/m$^3$, and $f = 10^{-4}$/s. The geostrophic equation in natural coordinates is

$$V_g = -\frac{1}{f \rho} \frac{\partial p}{\partial n},$$

and the gradient wind equation is

$$V = -\frac{f R}{2} \pm \sqrt{\left(\frac{f^2 R^2}{4} - R \frac{1}{\rho} \frac{\partial p}{\partial n}\right)}.$$

By convention, $R > 0$ is CCW. Show your work. Of the values you obtain, the smallest real wind speed value will be that associated with the regular cyclonic (CCW) low. Since we associate synoptic-scale cyclones with potentially large wind speeds, this result may not be intuitively obvious.

1. Compute the geostrophic wind speed, expressed in meters per second.

2. Let $|R| = 1000$ km (in absolute magnitude). Compute the gradient wind speed corresponding to the regular low (regular CCW cyclone). You should obtain a value that is smaller than the geostrophic wind speed, right?
3. Let $|R| = 1000$ km (in absolute magnitude). Compute the gradient wind speed corresponding to the anomalous low (CW). You should obtain a value that is much larger than the geostrophic wind speed, right?

4. Let $|R| = 1000$ km (in absolute magnitude). Compute the gradient wind speeds corresponding to the regular and anomalous highs (both are CW). Those are the two roots in the lower right quadrant of the chart I used in class.
5. The cyclostrophic equation is $V = \sqrt{-\frac{R}{\rho}} \frac{\partial p}{\partial n}$. Let $|R| = 1000$ km (in absolute magnitude). Solve for real values of the cyclostrophic low considering positive and negative values for $R$. You should get two identical values of $V$.

6. The inertial flow equation is $V = -Rf$. Let $|R| = 1000$ km (in absolute magnitude). Solve for a real value of the inertial flow $V$. Your result should suggest to you that since slow motions would be expected from this balance, $R$ cannot be this large in magnitude.
Part II: Thermal wind questions

7. The figure below depicts the zonal geostrophic wind ($u_g > 0$ for westerly) as a function of height for a Northern Hemisphere location. Vectors point towards where the wind is going (away from the source). Heights are given alphabetic labels. By listing their letters, designate the height(s) at which the north-south $\nabla T$ clearly and unambiguously vanishes by providing the letter representing the level, along with a brief justification.
8. The 1000 mb geostrophic wind is from the north. 1000-500 mb layer mean temperature is decreasing towards the north. Use your knowledge of the thermal wind relationship to answer these questions qualitatively:

(a) What is the direction of the geostrophic wind at 500 mb?

(b) What is the temperature advection? Answer: cold advection, warm advection, no advection.

(c) Is the temperature advection stronger, weaker, or the same at 500 mb compared to at 1000 mb?

(d) Suppose the wind observed at 500 mb is subgeostrophic. What could account for the wind speed being slower than the geostrophic value?